IODP Expedition 371: Tasman Frontier Subduction Initiation and Paleogene Climate

Site U1507 Summary

Background and Objectives

Integrated Ocean Drilling Program (IODP) Site U1507 (proposed Site NCTN-8A) is located in the New Caledonia Trough, ~460 km south of New Caledonia, ~620 km north of Deep Sea Drilling Project (DSDP) Site 206, and ~530 km east of DSDP Sites 208 and 588. The northern and central New Caledonia Trough, which is 1700 km long, has not been drilled previously. On the basis of evidence from DSDP Site 206 and the Taranaki Basin, which lies at the southern end of the New Caledonia Trough, it has been inferred that the New Caledonia Trough formed during Cretaceous rifting and subsequent subsidence. However, recent analysis of high-quality seismic-reflection data has led to an alternate hypothesis that the present physiography was created mainly during Eocene subduction zone initiation. Site U1507 was chosen to determine the timing of deformation and uplift of Norfolk Ridge, to constrain the age of trough formation and sedimentary fill, and to obtain a record of regional volcanism.

Operations

Hole U1507A (26°29.3158'S, 166°31.7039'E, water depth 3568 m)
Hole U1507B (26°29.3158'S, 166°31.7155'E, water depth 3568 m)

Hole U1507A was cored with the advanced piston corer (APC) system, retrieving Cores U1507A-1H through 26H with an average recovery of 106%. Temperature measurements were taken with Cores 4H, 7H, 10H, 13H, 16H, and 19H. Deployment of orientation and temperature tools was discontinued after Core 20H. Coring continued with the extended core barrel (XCB) system, retrieving Cores 27X through 46X with an average recovery of 55%. Hole U1507B was first drilled without coring from 0 to 376 m, then cored (Cores U1507B-2R to 53R) with an average recovery of 76%.

After dropping the coring bit at the bottom of the hole and replacing the hole with heavy mud, three logging passes were made with a modified triple combo tool string between 75.2 and 864 m WSF: a downhole log, a 125 m log up for calibration, and a main log up the entire hole. The modified triple combo logging tool string included magnetic susceptibility (MS), electrical resistivity, sonic, bulk density, and natural gamma radiation (NGR) tools.

Principal Results

Lithostratigraphy

The sedimentary sequence at Site U1507 consists of ~685 m of biogenic ooze and chalk interbedded with calcareous and volcaniclastic turbidites (Lithostratigraphic Unit I), overlying ~170 m of more homogeneous clayey nannofossil chalk (Lithostratigraphic Unit II). The sediments of Unit I are further divided into three subunits, based on changes in lithology and sedimentological features, as identified by macroscopic and microscopic (smear slide, thin section, and scanning electron microscope) core description.

Subunit IA (0–401.2 m CSF-A) mostly consists of white nannofossil ooze and chalk. This dominant lithology is accompanied by light greenish gray nannofossil-rich clay with volcanic ash, white gray normally graded foraminiferal ooze or limestone beds, and by a restricted ~2 m thick interval of very dark greenish gray volcanic breccia and tuffaceous sandstone. Soft-sediment deformation is widespread, but is particularly common in the lowermost part of the subunit.

Subunit IB (401.2–542.9 m CSF-A) is primarily composed of greenish gray clayey nannofossil chalk with volcanic ash showing significant soft-sediment deformation, interbedded with dark gray clayey tuffaceous sandstone and greenish gray clayey foraminiferal limestone with volcanic clasts. This subunit differs from Subunit IA by an overall increase in clay and volcanic content.

Subunit IC (542.9–685.5 m CSF-A) consists of dark greenish gray, coarse to fine grained tuffaceous conglomerate, sandstone and tuff, alternating with light greenish gray clayey nannofossil chalk with volcanic ash. The boundary with Subunit IB is defined by the first occurrence of a thick-bedded tuffaceous conglomerate. Volcaniclastic lithologies display a full range of sedimentary facies that point to deposition from various gravity flow processes, from debris flows to turbidity currents. Thin sections and X-ray diffraction measurements on the volcaniclastics reveal that clast lithologies consist of variable percentages of basaltic minerals, such as pyroxene, plagioclase, and olivine phenocrysts, as well as volcanic glass shards, vesicular pumice, and large benthic foraminifera.

Lithostratigraphic Unit II (685.5 m to 855.7 m CSF-A) consists of homogeneous, light greenish gray bioturbated clayey nannofossil chalk, with common *Zoophycos*, *Nereites,* and *Spirophyton* burrows, and rare foraminiferal limestone beds. The lithology is consistent with hemipelagic-dominated sedimentation. Very rare foraminiferal limestone beds, with few volcanic grains, are still encountered in this subunit. At 826–836 m, the lithology changes to a greenish gray nannofossil claystone, possibly reflecting increased carbonate dissolution.

Biostratigraphy and Paleoenvironment

Nannofossils and foraminifera were present throughout Holes U1507A and U1507B, providing a robust stratigraphy: Plio-Pleistocene (6.2–177.8 m), Miocene (187.0–432.6 m), late Oligocene (449.9–520.0 m), early Oligocene (523.1–639.1 m), and late to middle Eocene (642.3–855.7 m). The Oligocene/Miocene boundary can be approximated using the top of *Sphenolithus delphix* (~442.5 m). The Eocene/Oligocene boundary can be approximated using the top of planktic foraminifera *G. euapertura,* the benthic foraminifera *N. truempyi*, the base acme of calcareous nannofossil *Clausicoccus subdistichus*, and the top of rosette discoasters.

The occurrence of *O. beckmanni* in samples from 835.5 to 836.1 m constrains these depths to the planktic foraminifera Zone E12 (40.03 to 40.43 Ma), which effectively marks the Middle Eocene Climatic Optimum (MECO). For calcareous nannofossils, the base of *D. bisectus* at ~836.1 m and the top of *S. obtusus* at ~825.6 m indicate the post-MECO interval was recovered in this interval. However, Core 51R (835.7–836.1 m) only recovered 38 cm (4%), so most of the MECO was washed away or lost during coring.

Radiolarians have a patchy record. Well-preserved Neogene radiolarians are found in samples from 6.2 to 54.1 m. Samples at 63.4 and 82.5 m contain moderate to well-preserved early Miocene or late Oligocene radiolarian assemblages. However, the interval from 92.0 to 258.5 m is either barren of radiolarians or contains only rare specimens. Rare to common middle to late Eocene radiolaria are found in samples from 263.6 to 855.7 m. Rare, heavily recrystallized, possibly Cretaceous radiolaria are present in several core catcher samples. Low-latitude index species are absent or rare.

Benthic foraminifera indicate a lower bathyal paleodepth, and in some intervals (e.g., ~205.6 m) their assemblages contain a mixture of deep and relatively shallow taxa with different preservation states. A palynological reconnaissance study, carried out on 10 core catcher samples throughout the sedimentary sequence, showed that deposits at Site U1507 are effectively barren of palynomorphs. Ostracods were rare to common between 6.2 and 279.7 m, and absent in Hole U1507B, except for one sample.

Paleomagnetism

Paleomagnetic measurements on section halves from Holes U1507A and U1507B show variable quality for different lithological units. At Hole U1507A, the natural remanent magnetization (NRM) intensity is in the range of 10^{-2} A/m, and increases from 234 m downhole by about one order of magnitude. The NRM inclination is mostly positive, likely the effect of a present-day geomagnetic overprint. After alternate field (AF) demagnetization cleaning at 20 mT, the interval 0 to 54.1 m is characterized by dominantly normal polarity, with some intervals of reverse polarity. Between 53.7 and 215.6 m some swings between positive and negative inclination are observed, without a clear bimodal clustering, and from 216 m downhole inclinations are less stable. This may reflect some combination of drilling-related deformation, depositional processes, and weak magnetization. The average inclination for Hole U1507A is around −20°, and no reliable shipboard magnetostratigraphy can be obtained for this hole.

High-quality paleomagnetic data were obtained from Hole U1507B, with a well-defined series of normal and reversed polarity intervals in lithostratigraphic Unit I. Viscous overprint was removed with a 20 mT AF demagnetization. Inclination values for Unit I after 20 mT AF demagnetization have two clear peaks clustered around −40° and 45°. High-quality AF demagnetization behavior is observed in 59 out of 72 discrete samples from Hole U1507B, and results are in excellent agreement with the pass-through paleomagnetic data. The overall high quality paleomagnetic data from Hole U1507B can be attributed to the high NRM intensity and good recovery of lithified sediment cores. Integration with biostratigraphic results shows that the interval between 433.3 and 682.9 m contains most polarity chrons from Chron C6Br in the early Miocene through Chron C16n in the late Eocene.

Sediments from lithostratigraphic Unit II generally show scattered inclination values without recognizable bimodal distribution. Two inclination changes at 759.3 m and 834 m are tentatively correlated with the base of Chron 17n and Chron C18n, respectively.

Anisotropy of magnetic susceptibility (AMS) was measured on 123 discrete samples from Site U1507, which were collected in the most undisturbed intervals and often on top of turbidite layers. The soft and magnetically weak sediments from Hole U1507A did not yield well-defined orientations of the AMS tensor. Cube samples from lithified sediment, however, show a clear oblate magnetic fabric, where the minimum axis of the AMS ellipsoid is statistically oriented perpendicular to the bedding. AMS data confirm that the paleomagnetic directional data obtained by the same samples are reliable and not affected by synsedimentary deformation.

Petrophysics

Cores recovered from Holes U1507A and U1507B were analyzed with the full suite of physical property measurements. Downhole temperature measurements were made in Hole U1507A, and wireline logging was completed using a modified triple combo tool string in Hole U1507B.

Bulk density increases with depth from the seafloor (1.5 g/cm^3) to bottom of hole (2.4 g/cm^3), with local decreases to ~1.6 g/cm^3 observed between ~420 and ~500 m. Moisture and density (MAD)-derived porosity values correspondingly decrease from ~70% in nannofossil ooze at the top of Hole U1507A to ~25% at the base of Hole U1507B in nannofossil chalk. Grain density is ~2.71 g/cm^3 to ~300 m, then varies between 2.7 and 2.8 g/cm^3 to ~700 m, except for the interval ~420–500 m, where grain density conspicuously drops to 2.6–2.7 g/cm^3. In lithostratigraphic Unit II, grain density decreases again to ~2.5–2.7 g/cm^3.

P-wave velocity measured on cores gradually increases downward in Subunit IA, with more rapid increase around 290 m corresponding to diagenesis of ooze to chalk. From ~400 m to 520 m, *P*-wave velocities increase from 2000 to 2500 m/s, and stay at similar values to the base of the hole. *P*-wave velocities from wireline logging increase from 2300 to 2700 m/s within Unit II, with a negative excursion to ~2400 m/s associated with the MECO at ~835 m.

Thermal conductivity increases gradually with depth from 1.1 to 1.8 W/m·K in Subunit IA, and show a decreasing trend in Subunits IB and IC. In Hole U1507A, six temperature measurements were made with the APCT-3 tool, yielding a temperature gradient of 46.9°C/km.

MS is low (<50 IU) in Subunits IA and IB, and high (up to 1000 IU) within Subunit IC. Below 680 m, values decrease to ~40 IU and are constant in the lowermost part of the hole. NGR measured on cores and by wireline logging show matching downhole variations. NGR is low, except for positive excursions of ~20–40 counts/s between 400 and 520 m and 520–680 m.

Changes in color reflectance occur at the base of Subunit IA, where all parameters decrease, reflecting the darker and greener clay-rich sediments. A slight increase in lightness (L*) is observed at the top of Unit II.

Sediment vane shear strength increases from ~18 kPa near the seafloor to ~50 kPa at ~250 m. Compressive strength from penetrometer measurements increases from 0 kPa near the seafloor to ~80 kPa at ~75 m, and varies between ~50 and ~300 kPa farther down to ~250 m, where sediment is too hard to measure.

Geochemistry

Headspace gas samples were routinely collected from each core from Holes U1507A and U1507B. Hydrocarbon gas concentrations in all samples were below detection limit.

A total of 56 interstitial water (IW) samples were collected from Cores U1507A-1H to 45X (51 samples) and Cores U1507B-6R to 14R (five samples). The results show a distinctive difference between above and below 250 m, corresponding to the change from APC to XCB or rotary coring. The IW constituent profiles are smooth in the upper 250 m and become scattered below 250 m. Despite this issue, Mg, K, and SO_4^{2-} generally decrease while Ca increases downhole. Dissolved Sr increases smoothly in the upper 160 m and then remains approximately constant with depth. The negative correlation between dissolved Ca and Mg concentrations suggests reactions between volcanic material and pore water in the sediment column. The downhole decrease in SO_4^{2-} suggests sulfate reduction of particulate organic carbon, which also explains the rise in dissolved NH_4^+ with depth.

Samples for solid sediment analysis were taken at a sampling resolution of at least one sample per core from Holes U1507A and U1507B. Carbonate contents are very high (>90%) throughout Subunit IA. Decreasing carbonate contents (30%–70%) towards the middle of Subunit IB and IC correlate well with changes in other properties, such as decreasing reflectance L*, increasing MS, and increasing NGR. Interbedded darker-colored layers are represented by lower total carbon and carbonate contents (~20%). Carbonate contents within Unit II are high, varying between 50% and 80%. TOC contents are low (averaging 0.4%) throughout the sediment column and do not differ significantly between Units.

Stratigraphic Correlation

Magnetic inclination and NGR data were used to establish a tie from the base of Hole U1507A to the top of Hole U1507B. Interval U1507A-46X-2, 100 cm, was tied to U1507B-6R-2, 140 cm. NGR measured on cores from both Hole U1507A and Hole U1507B were successfully correlated to the downhole logging natural gamma ray data, confirming the tie.

Age model and sedimentation rate

Linear sedimentation rates (LSR) and mass accumulation rates were calculated for Site U1507 using paleomagnetic and calcareous nannofossil datums on the CSF-A depth scale. The record recovered at Site U1507 is remarkably continuous despite the numerous turbidite deposits and seismic reflectors and sequences, and includes the entirety of the Oligocene. LSR in the mid- to late Eocene vary between ~30 and 60 m/My, but decrease near the Eocene–Oligocene Transition to ~15–20 m/My. An extended duration of low LSR (~12 m/My) characterizes the Oligocene to middle Miocene, except for two short time intervals of enhanced LSR (30 to 29 Ma, and 25 to 23 Ma). After 9.5 Ma, LSR stepwise increase up to 40 m/My at 7.4 Ma, and remain at these high values until 4.0 Ma. This pulse in sedimentation, which is characterized by constant, high carbonate contents, may correspond to the late Miocene to early Pliocene “biogenic bloom” as documented at other sites. The uppermost 4 My at Site U1507 are represented by a relatively condensed section with LSR <4 m/My.

Mass accumulation rates follow the trend observed in LSR and vary between 2 to 12 $g/cm^2/ky$.